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Development of a smart cricket ball for advanced performance analysis of bowling

Batdelger Doljin*, Franz Konstantin Fuss

School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne VIC 3083, Australia

Abstract

Cricket bowling requires high level of skills in many ways (e.g. physically and mentally). The ball delivery technique is one of these important skills which can be optimised with advanced training methods. These training methods hinge on advanced performance parameters. Development of a low cost smart cricket ball will address the shortcomings of the existing systems and discover and explore cricket bowling kinematics and dynamics. In the past cricket bowling kinematics has not been properly studied using instrumented balls due to technical limitations of sensor system and electronics design. The aim of the project was to develop a highly portable instrumented cricket ball for recording the ball's kinematics and calculating dynamic performance parameters from kinematic data. The ball is designed in such a way that it exactly feels and looks (i.e. mass and material) as a real cricket ball. The ball is constructed from leather hemispheres, an impact proof Nylon6/6 nutshell, a shock damping foam material, and miniaturized electronics circuit.

Peer-review under responsibility of School of Engineering, Faculty of Science Engineering & Built Environment, Deakin University

Keywords: Cricket ball; bowling; instrumentation; rate gyroscopes; spin rate; spin axis; vector diagram; smart sports equipment

* Corresponding author. Tel.: +61 3 9925 6123; fax: +61 3 9925 6108.
E-mail address: s3458456@student.rmit.edu.au

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1. Introduction

High-Tech sports instruments are rapidly increasing in today's global market. One of the reasons is MEMS sensor's technological advancement. For example Analog Devices Inc has developed quad-differential MEMS gyros which combine four separate sensing elements to cancel out the effects of vibration, noise and the influence of linear acceleration. Such sensors provide the opportunity to develop smart ball for performance analysis and research from different angles. The first instrumented cricket ball was developed by Fuss and co-workers for research purposes [1-4], consisting of a Logomatic data logger, three high rate gyros (± 50 rps), and a battery. The data sampling frequency of this ball was 500 Hz on each channel, and the data was downloaded via USB port. The ball had to be opened for switching on and off, and for downloading data. The ball was CNC machined of Ureal and the seams were glued onto the ball's surface.

The aim of this paper is to give an overview of the development of the second prototype of the RMIT Smart Cricket ball.

2. Materials and methods

The second prototype of the smart cricket ball includes three high-speed gyros (7g), microcontroller (7.2g), battery (4.8g), memory, and electronic equipment for wireless data transfer and inductive charging. The ball is operated wirelessly via laptop or smart phone. The mass of the ball is 160 g and it is fully balanced. The electronics is protected by foam, a CNC-machined nylon6/6 shell and the ball is encased by the leather hemispheres of a cricket ball (Figures1 and 2). The data sampling rate of the ball is 815 Hz. The z-axis of the coordinate system is perpendicular to the seam, and the ball is held such that in right-/left-handers, the positive/negative z-axis points towards the palm (spin bowling) or the middle finger (fast bowling). This convention ensures equal kinematics for right- and left-handers with respect to the ball's coordinate system.

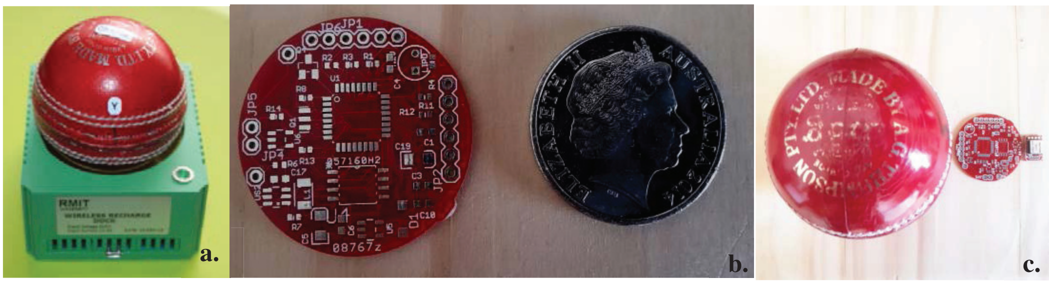

Figure 1: a) Instrumented Smart cricket ball on the wireless charger. b) Main printed circuit board is compared to an Australian 20cents coin. c) The size of the printed circuit boards is compared to the size of a cricket ball

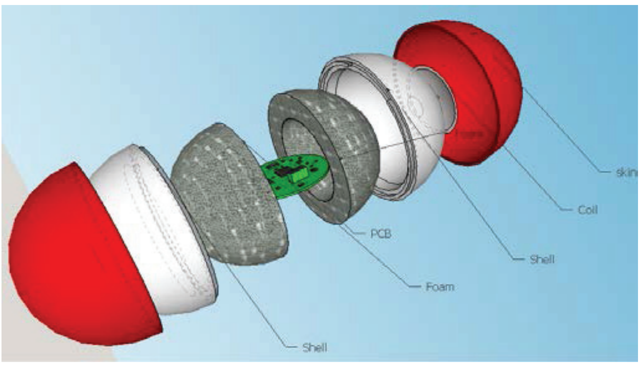

Figure 2.Exploded view of the RMIT Smart Cricket Ball

2.1. Electronics

The electronic circuit was developed for instrument the cricket ball to record angular velocity data during the cricket bowling action for research and performance analysis. The surface mount components (TQFP, BGA etc.) have been chosen to miniaturize printed circuit board design (Figure 1).

Figure3 illustrates a block diagram of the electronic circuit which was designed for smart cricket ball. The circuit consists of a power supply, microcontroller, three rate gyros, radio transceiver and data storage. Main components of the power supply circuit are Qi V1.0 wireless power receiver, proximity power switch, voltage booster, 3.7V Lipo battery and a charger. Qi is the global standard that was developed by the Wireless Power Consortium. This means that the smart cricket ball can be recharged on any Qi certified wireless charger. The average power consumption of the whole circuit is about 30ma and total running time is ~5 hours based on 150mah battery capacity. A magnetic proximity switch has been used for powering up the smart ball without opening it. The smart cricket ball complies with IP67 standard (Ingress Protection against water and dust) as the components such as wireless charging, Bluetooth transceiver and proximity switch are completely sealed. Therefore, the ball can be used outdoors in any weather condition.

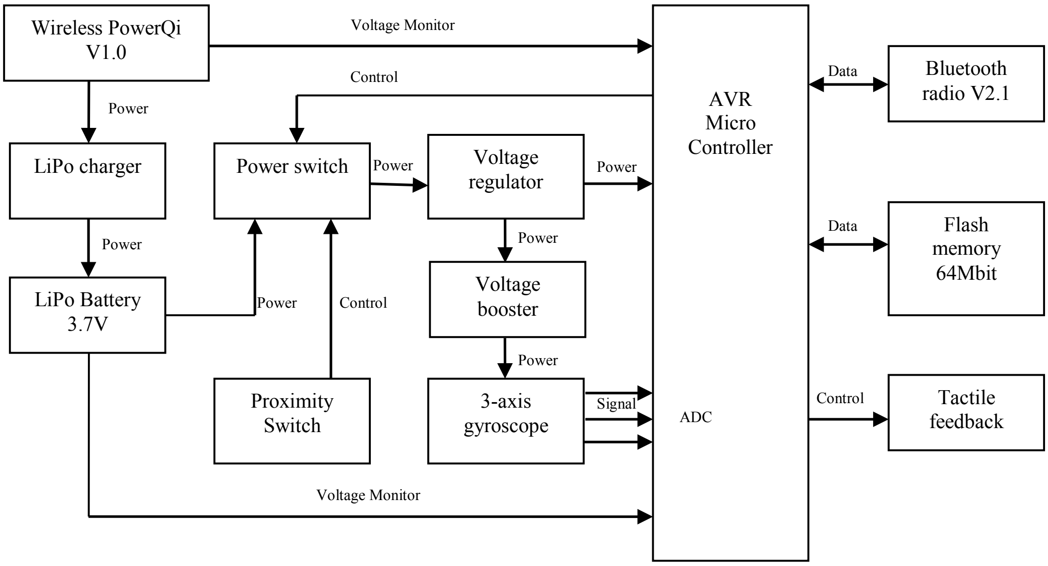

Figure 3: Block diagram of electronic circuit of RMIT Smart cricket ball

A low power AVR RISC-based microcontroller (ATmega328p ATMEL) monitors and communicates with other peripherals. The microcontroller has a built-in 10 bit ADC (Analog to Digital Convertor) which converts sensor's analog output signal to digital format and stores it to a flash memory. The sampling frequency of the ADC was set to 815 Hz for each of the three channels. A tactile feedback (vibrator) system was implemented for passing information to the bowler (e.g. Start, Stop, Battery and Memory status). The three rate gyros are aligned orthogonally to the ball's coordinate system and measure up to ±50rps. The electronic circuit was equipped with on board 64Mbit flash memory (MX25L6435E Macronix) for data storage. Stored data will be kept safe even when the battery is fully discharged. The memory can hold up to 28 minutes worth of data at sampling rate of 815SPS. For example, the average bowling duration is 20s and therefore the ball will record about 80 bowling sessions. A Bluetooth V2.1 Class 1 radio transceiver was used as transmission link between PC, Android or IOS mobile devices for downloading and uploading data. The transmitting distance ranges up to 100m at 16 dBm RF output power.

2.2. Software

Mobile Applications were developed for Android devices to control the functions of the smart cricket ball and offload the recorded data (Figure 4a). MIT App Inventor mobile application programming tool was used for this particular application. Also, for post data processing, a GUI (Graphical user interface) software package was developed which processes the data and calculates the performance parameters in the Microsoft Windows environment. Equally, a 2D/4D graphical visualization software is included in this package. (Figure 4b). The post-processing and graphical visualization software was written in Python programming language. Therefore, the software can be used across different platforms (e.g. Windows, MAC OS, and Linux).

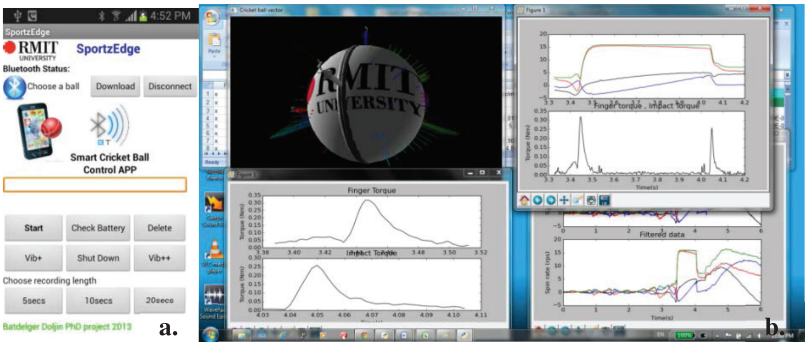

Figure 4: Screenshots a) Control Application for Android device b) Post processing software running on Windows7

2.3. Firmware

The firmware was developed as an analog voltage data logger to record output of the three high speed gyroscopes at sampling rate of 815 Hz. Additional functions embedded to the firmware are power saving, data checksum, support terminal modes, remote firmware upgrade, bias calibration and live data stream.

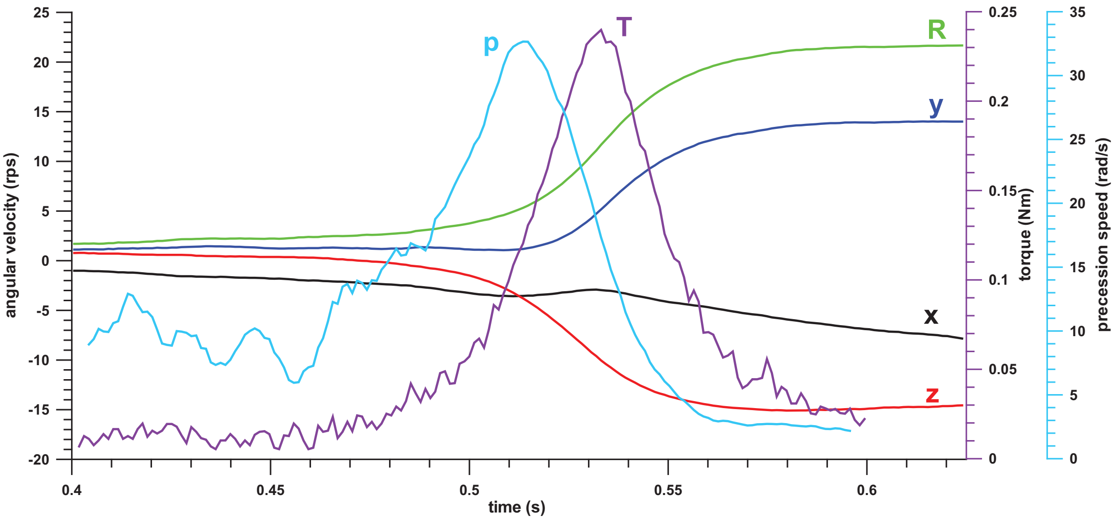

Figure 5.Processed data visualized in 2D graphics; x,y,z = angular velocity measured by the three gyros; R = resultant angular velocity; T = torque; p = precession speed of the angular velocity vector.

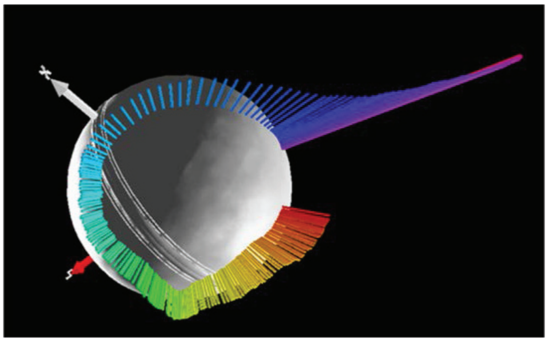

Figure 6. Processed data visualized in 4D graphics

3. Results

The results obtained from the smart ball are exemplified for an off-spin delivery. When rotating the arm, the spin axis vector is still of short length (low spin rate) followed by a rapid increase in spin rate, when torque is imparted onto the ball. For average release spin rates of 23 rps, the maximal torque is approximately 0.29 Nm (Figure 5). The precession of the spin axis is generated by the torque, causing the spin axis vector to follow the torque vector. For average release spin rates of 23 rps, the maximal precession is approximately 35 rps. When all the calculated data is plotted in 3D with colour-coded time information (4D; Figure 6) then the movement of the spin axis is easier to understand than in 2D graphics (Figure 5).

4. Discussion

A smart ball has a number of advantages over existing performance analysis instruments (e.g. motion analysis and Doppler radar system): the ball kinematics can be determined outdoors and the aerodynamics of the ball is not disturbed by markers. Furthermore, the ball is portable, inexpensive, easy to use as trained operators are not required, and provides more accurate data.

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